The Role of Design Drawing Among Children Engaged in a Parachute Building Activity

Dougal MacDonald and Brenda Gustafson

Introduction

In recent years, many elementary (ages 5-12) science programs in North America have incorporated what is called design technology, design and technology, technology, technological problem-solving, and/or problem-solving through technology (ITEA, 2000; Alberta Education 1996; Kimbell, Stables & Green, 1996; Layton, 1993). Design technology involves designing and making products to meet some need, and is "directly concerned with the individual's capacity to design and make, to solve problems with the use of materials, and to understand the significance of technology" (Eggleston, 1996, p. 23). In elementary classrooms, lessons often focus around designing and building models of structures and mechanisms such as bridges and vehicles.

Design technology involves children in problem-solving processes perceived as central to the development of their capability to do quality work. These processes have been referred to as procedures, procedural skills, facets of performance, facets of capability, problem solving skills, and thinking processes (Bottrill, 1995; Custer, 1995; Johnsey, 1997; Kimbell, Stables, & Green, 1996). Examples include investigating, planning, modeling, making, and evaluating. One activity that plays an important role in many of these problem-solving processes is drawing. Drawing can be a method of recording information, a component of planning, and/or a technique of two-dimensional modeling.

The two main approaches to studying design drawing have been to investigate the practice of design professionals such as architects and engineers, and to explore children's classroom design technology drawing. These approaches raise at least three important issues from which the focus questions for the present study are derived:

- What are the characteristics of children's design technology drawings?
- Could an analytic scheme, derived from professional drawing practice, be used to analyze children's design technology drawing?
- How might teachers intervene in order to enhance and broaden children's authentic use of drawing in design technology?

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Related Research

Classroom Drawing Practice

Recent research on classroom drawing practice in design technology has focused on four main areas:

- The role of drawing in creating and developing ideas
- The link between drawing and making
- The respective roles of 2-dimensional drawing and 3-dimensional modeling
- The effects of the explicit teaching of drawing

Several researchers (Garner, 1992, 1994; Anning, 1997; Hope, 2000; Smith, 2001) state that much classroom design technology drawing overemphasizes the role of drawing in communicating ideas and under-emphasizes its role in creating and developing ideas. Garner notes the undervalued role of drawing in the manipulation and exploration of design. He claims that much professional design drawing is never seen by others and that its main purpose is to assist the designer to create and develop ideas rather than to communicate with others (Garner 1992). He also points out that an advantage of sketching is its ambiguity, making it a useful medium for generating ideas (Garner, 1994).

Anning (1997) notes that "drawing offers a powerful mode for representing and clarifying one's own thinking" (p. 219). She asserts that young children use drawings to explore and generate ideas, similar to designers. Hope (2000) concludes that the overwhelming focus of research on children's drawing has been on drawing as representation whereas "the activities most closely associating drawing with designing are those of investigating and generating ideas" (p. 108). Smith (2001) suggests that too much emphasis on representation, i.e., the perfect drawing, could restrict opportunities for discovering new ideas.

Researchers (Rogers, 1998; Hope, 2000; Fleer, 2000) have also investigated the link between children's design plans and what they make. Rogers studied young children as they designed, made, and appraised vehicles using commercial kits. He found a weak link between the designing stage and the making and appraising stages of their work in that children did not refer back to their design drawings when making. He suggests three possible reasons for this disconnection: lack of a clear idea of what designs should look like, not understanding the purposes for drawing a design, and deficits in drawing skills (Rogers, 1998).

Hope (2000) explored how young children use drawings in planning a product. He concluded that more understanding is needed about how children develop drawing skills. Fleer (2000) found that even some very young children use their drawn plans as a guide to making. She suggests that two possible reasons some children do not use drawn plans are insufficient technical knowledge and insufficient detail in their plans.

Some researchers (Smith, 2001; Welch, 1998) have investigated the respective roles of two-dimensional (drawing) and three-dimensional modeling in classroom design technology. Welch (1998) found that Grade Seven students quickly replaced drawing with three-dimensional modeling, i.e., working with the project materials. He calculated that students spent only about 8.5% of their total design time sketching and drawing (Welch 1998). Similarly, Smith notes that pupils in England appeared reluctant to use 'sketch modeling' (Smith 2001).

An interesting sidelight on the findings regarding 2D and 3D modeling is that many professional designers recognize that the degree of abstraction in a design is controlled by the form of the modeling. Drawings are simpler and more abstract than 3D models, hence they are more ambiguous and allow for more interpretation (Lindsey, 2001).

A number of researchers advocate explicit teaching of drawing skills (Anning, 1997; Rogers, 1998; Fleer, 2000; Smith, 2001). For example, Anning (1997) proposed that teachers could do more to enhance children's graphicacy through explicit teaching of drawing, as well by becoming more aware of how graphicacy can contribute to children's learning. She urges more research into developing graphicacy in educational and non-educational contexts.

Fleer (2000) advocated assisting children in their drawing through teaching interventions such as making them more aware of the specific purposes of drawing and familiarizing them with different perspectives. Smith (2001) advocated further research into sketching as an important aid to designing. He suggested that a better understanding is needed into "how to develop pupils' sketching skills which provide opportunities for ambiguity and hence an opportunity for creating new ideas" (p. 8).

Some investigators have studied the effects of explicit teaching of design drawing. Welch, Barlex, and Lim (2000) investigated whether explicit teaching better enabled Grade Seven students to use two-dimensional modeling to help them design a case for audiotapes, videotapes, or CDs. They concluded that students tended not to use sketching to explore solutions but moved quickly to three-dimensional modeling. The researchers attribute this to limited sketching skills and experience. They speculate that different methods of modeling may be appropriate to different tasks.

Smith, Brochocka, and Baynes (2001) used explicit teaching of 2D and 3D modeling, including sketching, to determine how pupils used them. Pupils were instructed to move between 3D and 2D design media several times while working. The researchers concluded that "the revised approach was effective and this conclusion was confirmed by structured interviews with each of the pupils involved" (p. 125).

Professional Drawing Practice and Classroom Drawing Practice

There is a tradition of educators drawing on professional practice to inform classroom practice. For example, Robert Gagne's list of science processes, including observing, classifying, and predicting, was developed in the 1960s,

based on his observations of the methodologies of professional scientists (AAAS, 1967). These processes are still in the repertoires of science educators today. For another example, the writing process approach to written language, widely popularized by educators such as Donald Graves, originated with a 1964 article by Gordon Rohman, which drew upon how professional writers go about their work (Walshe, 1981).

While some researchers suggest that professional and classroom practice can inform each other (Davies, 1996), others caution against the unproblematic use of accounts of professional practice as prescriptions for classroom practice (Medway, 1994). Medway notes that "while the actions performed in both settings, school and work, may be similar at a behavioral level, their meaning will be quite different since the student works within a distinctively educational matrix of purposes, expectations, conditions and criteria (e.g., working for marks, without financial risk, etc.)" (Medway, 1994, p. 88). Medway suggests that one approach is to view what occurs in professional practice as "indicators of curricular possibilities" (p. 104) rather than as prescriptions.

Methodology

This study took place at an elementary school in a middle-class, urban neighborhood. Visits were made to one Grade 6 (ages 11-13) classroom during the teaching of a twelve-week unit that combined a science inquiry unit (*Air and Aerodynamics*) with a design technology unit (*Flight*). The twenty-seven children (14 male; 13 female) had been coded as Academic Challenge (high achieving) students.

The research presented in this paper focuses on two lessons in which the children designed, made, and tested model parachutes. These lessons were selected because in each lesson pupils were directed by their teacher to draw pictures of their parachutes. The parachute activities were scheduled towards the end of the unit and were presented by the teacher as a series of structured action tasks focusing on product construction and testing.

Data Collection

In this study, we assumed that children's thinking was expressed through their drawings as well as through their verbal discourse, writing, and actions. Drawings, audio-tapes, field notes, photographs, and written work provided information about children's efforts to frame, negotiate, and complete tasks.

Children's drawings and written work were photocopied. Audio recordings were made of whole class discussions and one group of four children's conversations. Field notes and photographic evidence were compiled to lend insight into children's actions and interactions within the group.

Data related to the teacher's perceptions of scientific and technological problem solving were also gathered through semi-structured interviews prior to and during the teaching of the unit. Anecdotal records were kept of informal conversations with the teacher that occurred prior to and after each lesson.

Lesson and interview transcripts were provided to the teacher and she was invited to amend or clarify the meaning of any verbal comments.

Data Analysis

The following analytic scheme and clue structure, based on a research methodology developed by Roberts and Russell (1975), was used to analyze children's drawings (Figure 1). The analysis involved comparing children's drawings to the scheme to detect similarities and variations. The analytic scheme and clue structure, therefore, was used as a lens through which to view the children's design drawings and as a way to derive helpful insights about the role of drawing in classroom design technology.

Table 1
Analytic Scheme and Clue Structure.

Category 1 - The drawings include a beginning sketch	
Clue A.	A sketch is made at the beginning of the project
Clue B.	The sketch indicates the pupil's initial thoughts/key ideas about the project.
Clue C.	The sketch is exploratory and conceptual rather than representational.
Clue D.	The sketch is made quickly and spontaneously.
Clue E.	The sketch includes images and words.
Category 2 - The drawings include elaborating and refining drawings	
Clue A.	A series of freehand and hard-line drawings are made during the project.
Clue B.	The drawings are shared with other members of the design team.
Clue C.	The drawings transform the ideas expressed in the initial sketch.
Clue D.	The drawings elaborate, refine, expand, and develop the pupil's initial ideas.
Clue E.	The drawings show increasing accuracy and detail, including dimensionally.
Category 3 - The drawings include a final presentation drawing	
Clue A.	A drawing is made at the end of the project.
Clue B.	The drawing is a recognizable representation of the finished product.
Clue C.	The drawing can be used by those outside the design process as a guide to making.
Clue D.	The drawing is hard-line, finished, precise, and detailed.
Clue E.	The drawing is labeled and measured.

The analytic scheme and clue structure were developed through analyzing research literature on how drawing is used in professional practice (e.g., by

people working in engineering, architecture, and industrial design). The theoretical perspective incorporates two main ideas:

1. Professional designers use drawing both to represent and generate ideas (Arnheim, 1969; Bucciarelli, 1994; Ferguson, 1999; Lindsay, 2001; Robbins, 1994).
2. Professionals use three types of drawings in their work: initial sketches, elaborating and refining drawings, and final presentation drawings (Crowe & Laseau, 1984; Do & Gross, 2001; Laseau, 1980; Robbins, 1994; Schenk, 1991).

Four features of drawings identified from descriptions of professional practice are (Cross & Cross, 1998; Ferguson, 1999; Fraser & Henni, 1994; Robbins, 1994; Steele, 1994):

1. Timing or when the drawings were made ('A' clues).
2. Intended audience ('B' clues).
3. Purpose of the drawings ('C' clues).
4. Salient observable characteristics ('D' and 'E' clues).

It should be noted that during the analysis that a clue may be sound but the observable evidence may be missing from the drawing. In such a case, plausibility will temporarily win over presence. That is, methodologically speaking, it is not a clear-cut test of a clue if the behavior does not occur (MacDonald, 1995). For example, the omission could be a function of the context of the lesson, the teaching strategy, and/or the experience of the teacher.

Following the analysis, a member check was performed for factual and interpretive accuracy and to provide evidence of credibility (Denzin & Lincoln, 2000; Janesick, 2000; Lincoln & Guba, 1985). An experienced science education researcher uninvolved with the generation of the analytic scheme performed the check by reviewing the drawings, data analysis, and study interpretations. The researcher was asked to affirm whether the analytic scheme had overall credibility and whether study interpretations and conclusions were an appropriate reflection of the data (Lincoln & Guba, 1985). This researcher's suggestions were incorporated into this paper.

Lesson Context

Lesson 1 - Constructing Model Parachutes (45 minutes)

The teacher began the lesson by reviewing activity expectations, constraints, and materials. Each child was instructed to make a model parachute displaying one canopy no larger than 30 cm x 30 cm, or else two or more canopies that together would not exceed this measurement. The teacher supplied materials not brought by the pupils. Parachute design was to be informed by concepts about flight addressed in previous lessons (e.g., properties of air, drag, and gravity) plus any other knowledge children could draw on. Once their parachutes were constructed, children were to draw a picture of their design.

The teacher also announced that the parachutes would be tested in the gymnasium on the second day. The children were urged to think ahead to the testing and consider potential design modifications to see if their parachute needed alterations. The children were encouraged to construct their best parachute design to test competitively against other children's designs.

The children worked in groups to make their parachutes and then draw their final designs. At the end of the class, all children presented completed or nearly completed parachutes. The teacher provided an extra half hour later in the day for completing the individual parachute drawings.

Lesson 2 - Testing Parachutes (105 minutes)

The teacher reviewed behavioral expectations and testing procedures before entering the gymnasium. Each child was directed to test his or her individual parachute by standing on a chair on the gym stage and then releasing the parachute. A parent volunteer would time the descent. The goal was to achieve the slowest possible descent.

After each group member had completed one drop, the group would discuss results and select one group member's parachute to modify for the second and final test. The teacher advised the children to discuss who had the slowest descent time, analyze what was good about the parachute and how it differed from faster parachutes, and then decide what to modify to make it the best. Children were urged to use all the information they had to improve their chosen parachute because they would only get one chance for the second test.

Once children were in the gym, a second Grade 6 teacher, whose class was also designing and testing parachutes, restated the testing rules and identified the testing method, drop height, and canopy size as control variables that would make for a fair test. Behavioral expectations were again reviewed. The children were given about 80 minutes to drop-test their individual parachutes, select one parachute for modification, carry out (or not carry out) modifications, and then re-test their final group design. Once the final test was completed, children were instructed to draw their final group design.

Findings

Sixteen children produced two drawings each of parachutes. The first drawing was made after each member of the group had built an initial parachute. The second drawing was made after the group had selected, modified (or not modified), and tested the individual group member's parachute that the group identified as the best. Each group member had to draw the same "best parachute" as their final drawing. Both drawings were done to provide a visual representation of what had been made rather than to explore or generate ideas. Thus, they were done carefully and over a long period of time rather than quickly and spontaneously. Although later drawings included both images and words, they were clearly representational rather than conceptual.

The first drawings made by each pupil of his or her own individual parachute could be categorized as elaborating and refining drawings.

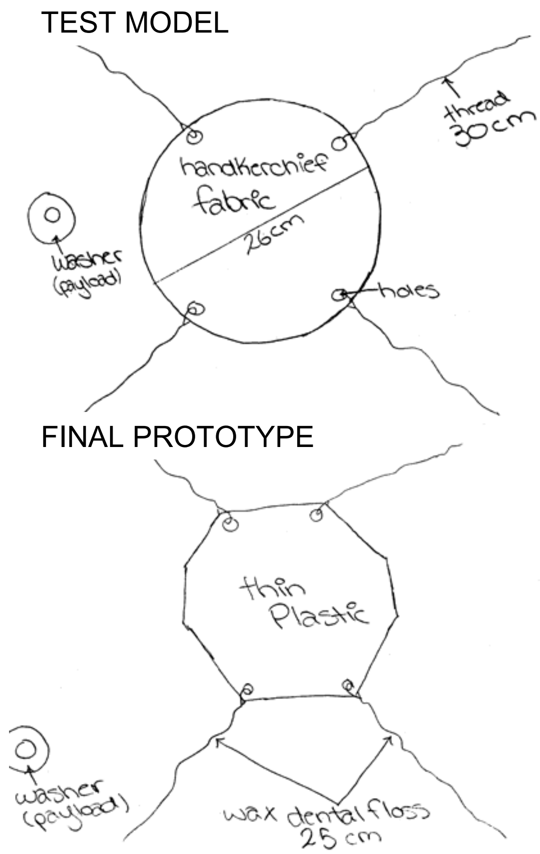


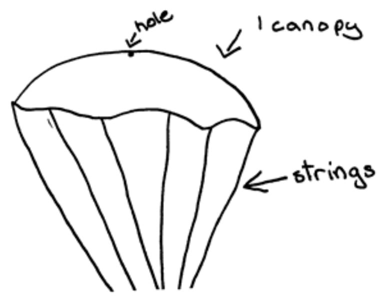
Figure 1. First Drawing Sample

This is because each pupil made a subsequent drawing of the group's single best parachute as a final drawing. At the same time, the first drawings also lacked most of the characteristics of the elaborating and refining drawings, as outlined in the analytic scheme and clue structure.

Each child made a single drawing of her or his own parachute. They then made a second drawing of the final parachute, which was, except in the case of the child who originated it, a parachute other than their own. Thus only in the case of one group member could the drawings be called part of a series (Clue A). The drawings of the individual and final parachutes were not shared with other members of the team except in an incidental way, for example, if a child wanted to show another child what he or she was doing (Clue B).

The drawings did not transform or build on the ideas in the initial sketch because there was no initial sketch (Clue C). It could however be argued that the second drawing did build on previous ideas in the sense that the final

TEST MODEL



FINAL PROTOTYPE

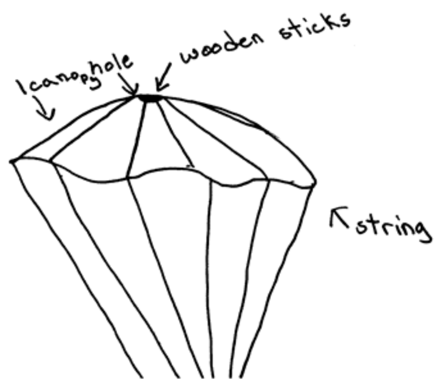


Figure 2. Second Drawing Sample

parachute represented the bringing together of the ideas of the whole group. Because the first drawings marked the end point of the individual parachute building, they did not provide scope for the refinement, expansion, or development of ideas (Clue D), except in the case of the one group member whose parachute was chosen for the second and final test. Finally, as only a single drawing was made, the issue of "increasing accuracy and detail" (Clue E) was a non-issue, except again in a general sense or specifically, in the case of the chosen parachute.

The second drawings made by each pupil were categorized as final presentation drawings. Out of the three categories of drawings, then, the clues for the final presentation drawings most closely matched children's drawings.

The second drawings were made at the end of the project and were a recognizable representation of the finished product (Clue A). Their purpose was to present their parachute to the teacher (Clue B). Most of the final drawings

could be used as a guide to creating the parachute that they depicted (Clue C). They were to a large degree finished, although not hard-line in the sense of being ruler-drawn (Clue D). The drawings were reasonably precise and detailed (Clue E). Almost all of them were labeled. Written on the drawings were descriptors such as “circular”, “holes”, “tape”, “string”, and “washers” (used as weights). Although the final drawings were not measured, some indication of proportionality was evident. For example, the sides of square parachutes were approximate equal in length and round parachutes were approximately round.

Discussion

Testing the Analytic Scheme

One purpose of the analysis of the drawings was to test the analytic scheme and clue structure for goodness of fit to the events of classroom teaching. The criteria are twofold (MacDonald, 1995):

1. Comprehensiveness and plausibility of the entire scheme for classroom.
2. Correspondence/discrimination of the individual clues to actual events.

The application of the scheme indicated that the framework was comprehensive enough to capture the main aspects of the lesson. In fact, the scheme was too comprehensive due to the limited use of drawing. In terms of what was in the lesson, a better test of at least part of the scheme would be to look only at the features of the third category of drawings, the final presentation drawings.

For the final presentation drawing, (e.g., the second drawings and for some children even the first drawings) the analytic scheme worked well. The clues were comprehensive enough to cover the main features of the drawings. All the clues were present to a degree that suggests they have plausibility for viewing classroom teaching events. For the overall lesson, the clues were also sound in that they discriminated instances of final presentation drawings from the other two types of drawings, as well as clearly indicated the absence of any drawings that had the characteristics of and fulfilled the purposes of initial sketches.

As in all studies, the selection of a teacher and the lessons was an issue. The test could have been performed using a lesson that incorporated opportunities to create the three categories of drawings described in the analytic scheme. At the same time, the literature suggests that the lesson analyzed was very representative in that the use of drawing was typical of many classroom design technology lessons (Anning, 1997; Fleer, 2000; Hope, 2000; Rogers, 1998; Smith 2001). Further, the application of a thoughtfully developed analytic scheme and clue structure to most lessons can generate useful insights about teaching and learning, as well as suggest guidelines for future research.

The teacher did not make very explicit the purposes of both kinds of drawings. In fact, the instructions to complete the drawings were almost cast as asides. But the timing and characteristics of the drawings indicate that their main purpose was to serve as records of the pupils’ products. The drawings

were made after the individual and group parachutes were completed and they were diagrammatic in nature, i.e., representational and labeled.

The initial thinking sketches were conspicuous by their absence. Drawing was conceived in this lesson solely as representation. It was not used to indicate initial thoughts, explore and conceive ideas, or as a vehicle for thinking but was used exclusively to depict the completed product. A balance was lacking between the two ways in which drawings are commonly used in professional practice, e.g., as representation and as a tool for thinking.

The importance of this finding lies not only in its contradiction with professional practice but in its significance for how the parachute task was implemented in the lessons. It is reasonable to assume that there may be links between the absence of the initial sketches and the implementation of the lesson because the task was chosen, set, and taught in a way that excluded initial sketching as an impetus for visual thinking. It is to these three contextual matters that we now turn.

Choosing Tasks

The task here was to make and test a model parachute. Design technology tasks are many and varied as any search of curriculum materials demonstrates. If pupils are to use initial sketching and subsequent drawings to generate and refine design ideas their tasks need to have the potential for a variety of designs. If the tasks have a very narrow range of possible solutions there is little need to create idea-generating sketches.

It is instructive, then, to look at the nature of the task itself as one aspect of considering how drawing was or could be used during design technology lessons. What kind of a task is making a parachute? A starting point is to observe that the modern-day parachute still resembles the one designed and drawn by Leonardo da Vinci in 1485. In fact, a recent test shows that a parachute built according to da Vinci's design could actually carry an individual safely to earth!

Why has the basic parachute design endured for centuries? A major reason is that a descending parachute is influenced and constrained by physical forces, including gravity (weight), lift, and drag (friction). The requirement to descend slowly amid the complex effects of these forces restricts how parachutes can be made. A parachute must be stable, light, and of limited area. It must keep its shape and maintain its balance. A means must be included to suspend the load being carried. These requirements place limitations on parachute design, as well as on the materials used to construct them.

Contrast making a parachute with a task such as creating a model shelter for a pet where restrictions of shape, size, and materials are much less an issue. A pet shelter can be of many different shapes, many different sizes, and can be constructed from a great variety of materials. Accomplishing the purpose of providing shelter is much more open-ended than accomplishing the purpose of descending slowly through the air.

It is instructive to note that the majority of the tasks that pupils carry out in design technology fall generally into one of two categories: architectural (aesthetic) tasks or engineering tasks. This distinction may need to be considered more carefully. Most architectural tasks are by nature more open-ended than most engineering tasks (if the engineering products are to be working models). Space can be enclosed by many different shapes and in many different ways, whereas wheels must be round. The differing natures of architecture and engineering suggest there may be more scope for visual thinking in architecture due to the wider number of options.

Setting Tasks

Another important issue in design technology is how the classroom teacher sets the task. In the present study most task setting was done by outsiders such as the absent regular classroom teacher, the other Grade 6 teacher, and the support resource developers who created the unit plans. The regular classroom teacher instructed the collaborating teacher who taught the lesson to follow and implement the two units of study, *Air & Aerodynamics* and *Flight*, as they were laid out in the support resource. This instruction was reinforced by the other Grade 6 teacher whose class was simultaneously doing the same units.

A distinction made by Kimbell, Stables, and Green (1996) is useful here. They place the setting of design technology tasks on a continuum of closed and open-ended. Closed-ended tasks are initiated "under conditions that provide very tight restraints" (p. 41). More open-ended tasks allow pupils to grapple with the challenges of "pinning down the task for themselves" (p. 41). Kimbell, Stables, and Green suggest that what is important to pupils is that they work in the "messy middle ground" (p. 43) between the two extremes.

In the parachute activity, pupils worked at much more at closed-end tasks, allowing them little space for beginning and ongoing sketches or exploratory thought. This, in turn, was somewhat dictated by the constant focus on making the slowest parachute. A more open-ended task would placed value on other aspects of design, such as aesthetics, and would take into account that real parachutes take a variety of forms for a variety of purposes.

Learning Purposes of Tasks

Kimbell, Stables, and Green (1996) also suggest that design technology tasks have two different kinds of purposes, "product purposes" and "teaching purposes" (p. 36-37). Product purposes have to do with what is made, with the product outcome. This purpose is necessary since it is part of the nature of technological tasks to create products.

Teaching purposes have to do with using the task as a vehicle for teaching something to pupils, such as conceptual knowledge, manipulative skills, technological problem-solving processes, appropriate attitudes, and/or group working styles (Kimbell, Stables, and Green, 1996). This purpose is necessary because classroom situations aim at learning rather than production for its own sake. In the parachute activity, for example, pupils could have learned more

about the role of drawing in technological problem-solving, as well as that sharing and discussing each others' drawings is a an appropriate group working style.

McCormick and Davidson (1996) state that there is often a tendency for product outcomes to exercise tyranny over teaching purposes and to take over the lesson. This would seem to be the case in the parachute lesson, with the overwhelming focus on creating the best parachute, i.e., the parachute having the slowest descent. This is what was rewarded and valued rather than the processes of thought leading to the final product.

The tyranny of the product purpose can override the teaching purposes. For example, in the parachute activity, some pupils misrepresented important conceptual knowledge about parachutes. Real parachutes have a hole in the top to make them more stable as they descend. But in the context of the product competition for the best parachute, some pupils deliberately omitted the hole to make their parachute descend more slowly.

Conclusions and Implications

Visual thinking is an important component of design technology but is often relegated to a minor role in classroom practice. Drawing in classroom design technology tends to emphasize representation over ideation. This is reinforced when design technology tasks are limited by nature, set in a restrictive manner, and emphasize product purposes over teaching purposes. Classroom interventions relating to the teaching of drawing and the teaching of design technology could redress this imbalance.

If teaching interventions can enhance pupils' abilities to use sketching not only as representation but also as a means of generating and thinking about design ideas, then the question becomes, "What types of interventions might be useful?" One possibility is to organize lessons around a framework that explicitly integrates the three types of drawing mentioned with the commonly identified phases of design technology problem-solving. A possible model is shown in Figure 3.

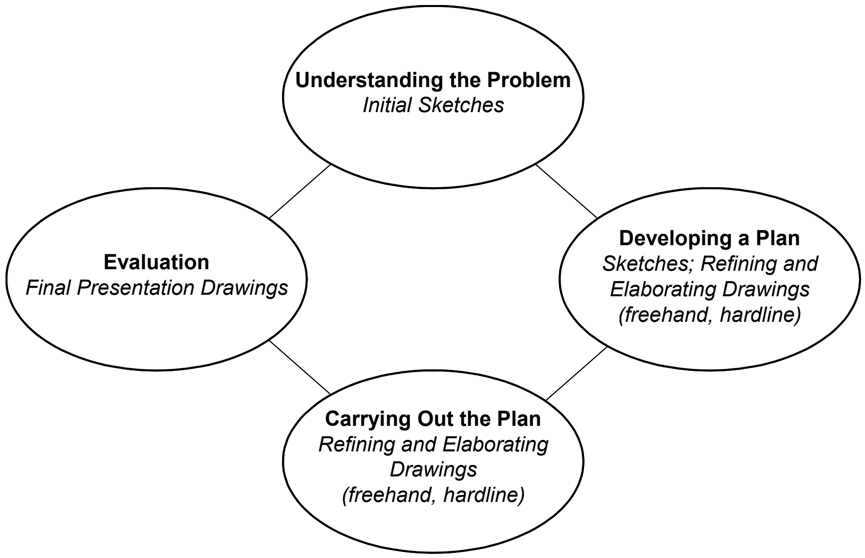


Figure 3. Integrated Drawing/Design Technology Problem-Solving Model

In the clue structure, each drawing is identified with an approximate time period in relation to the carrying out of the design technology project. Thus, each drawing can be mapped on to a different phase of the design technology problem-solving model. The use of such an integrated model could not only explicitly incorporate drawing but also influence the three important contextual issues noted in the study: choosing tasks, setting tasks, and framing the learning purposes. To accommodate the drawing component, the chosen tasks would need to:

- Allow scope for the meaningful use of drawing as an aid to planning and building.
- Be open-ended in regards to the potential solutions that could be developed through visual thinking.
- Incorporate learning purposes beyond the product purpose, e.g., include teaching purposes such as conceptual knowledge, manipulative skills, technological problem-solving processes, appropriate attitudes, and/or group working styles.

The analytic scheme and clue structure used in this study, derived from professional practice, proved useful in analyzing the use of drawing in a classroom design technology lesson. Although the chosen lesson utilized drawing in a limited manner, this was also typical of current design technology teaching. Notwithstanding, the analysis still generated useful insights, as well as provided a basis for a proposal as to how to explicitly integrate design drawing into design technology in a more meaningful way. A future research project

could test the classroom use of the integrated drawing/design technology model depicted in this paper.

The notion that the purpose of design drawing is solely to represent objects is likely a common misconception outside the design world. This is true among curriculum developers, teachers, and pupils. Professional development initiatives are important here and can help to broaden the perspective of key stakeholders. The literature on constructivism and conceptual change teaching may be helpful, for example, in starting the process of change by bringing to light prior conceptions about the role of design drawing. At the same time, this need to know even more about the subject matter puts an additional responsibility on overburdened elementary school classroom generalists.

An overall guiding notion for the use of drawing in design technology is balance. In classroom design technology there needs to be balance and ongoing dialogue between drawing as representation and drawing as ideation, between closed-endedness of tasks and open-endedness of tasks, and between product outcomes and teaching outcomes. Through balance, both teachers and students can experience how different types of drawings enrich the representation and generation of ideas during the problem-solving process. Using drawings as a tool to enhance visual thinking can help students both improve their design technology performance and to become more aware of design technology practice in the real world.

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